AR^{k}STORM — A West Coast Storm Scenario

D. A. Cox; L.M.Jones; F.M. Ralph; M.D. Dettinger; M. Hughes; K. Porter; S.C. Perry; P.L. Barnard; D. Hoover; C.J.Wills; J.D. Stock; W. Croyle; J.C. Ferris; G.S. Plumlee; C.N. Alpers; M. Miller; A. Wein; A. Rose; J. Done; K. Topping

Abstract

The United States Geological Survey (USGS) Multi-Hazards Demonstration Project (MHDP) is preparing a new emergency-preparedness scenario, called **AR^{k}Storm**, to address massive U.S. West Coast storms analogous to those that devastated California in 1861–62. Storms of this magnitude are projected to become more frequent and intense as a result of climate change. The MHDP has assembled experts from the National Oceanic and Atmospheric Administration (NOAA), USGS, Scripps Institute of Oceanography, the State of California, California Geological Survey, the University of Colorado, the National Center for Atmospheric Research, and other organizations to design the large, but scientifically plausible, hypothetical storm scenario that would provide emergency responders, resource managers, and the public a realistic assessment of what is historically possible.

The **AR^{k}Storm** is patterned after the 1861–1862 historical events but uses modern modeling methods and data from large storms in 1969 and 1986. The **AR^{k}Storm** draws heat and moisture from the tropical Pacific, forming Atmospheric Rivers (ARs) that grow in size, gain speed, and, with a ferocity equal to hurricanes, slam into the U.S. West Coast for several weeks.

Using sophisticated weather models and expert analysis, precipitation, snowlines, wind, and pressure data the modelers will characterize the resulting floods, landslides, and coastal erosion and inundation. These hazards will then be translated into the infrastructural, environmental, agricultural, social, and economic impacts. Consideration will be given to catastrophic disruptions to water supplies resulting from impacts on groundwater pumping, seawater intrusion, water supply degradation, and land subsidence. Possible climate-change forces that could exacerbate the problems will also be evaluated.

In contrast to the recent U.S. East and Gulf Coast hurricanes, only recently have scientific and technological advances documented the ferocity and strength of possible future West Coast storms. A task of **AR^{k}Storm** is to elevate the visibility of the very real threats to human life, property, and ecosystems posed by extreme storms on the U.S. West Coast. This enhanced visibility will help increase the preparedness of the emergency management community and the public to such storms.

AR^{k}Storm is scheduled to be completed by September 2010 and will be the basis of a statewide emergency response drill, Golden Guardian, led by the California Emergency Management Agency in 2011.

A History of Extreme Storms in California

Beginning on Christmas Eve, 1861, and lasting 45 days, an extreme series of storms struck California.

The storms caused severe flooding, turning the Sacramento Valley into an inland sea. In southern California lakes were formed in the Mojave Desert and the Los Angeles Basin. The 1861–62 series of storms were probably the largest and longest California storms on record.

Despite the historical and prehistorical evidence for extreme winter storms on the West Coast, the potential for these extreme events has not attracted public concern, as have hurricanes.

Storms of this magnitude have occurred in the past and are projected to become more likely as a result of climate change.

Preparing for the Next Extreme Storm

The USGS Multi-Hazards Demonstration Project (MHDP) uses hazards science to improve communities' resiliency to natural disasters, including earthquakes, tsunamis, wildfires, landslides, floods, and coastal erosion.

The USGS MHDP is now preparing for its next major public project, a winter storm scenario called **AR^{k}Storm**. Experts will design a large and scientifically plausible physical event, followed by an expert analysis of the secondary hazards and the physical, social, and economic consequences.

In 2009, the **AR^{k}Storm** atmospherics team completed a state of the art, scientifically credible meteorological model from records of the 1969 and 1986 storms.

Experts will examine in detail the following:

- The cost and consequences of floods, landslides, coastal erosion, and inundation
- Debris flow potential
- Environmental effects
- Physical damages—dams and levees, water and wastewater, roads and highways, and utilities

Consideration will be given to the following:

- Vulnerabilities associated with large-scale disruption to infrastructure
- Agricultural damages and losses and economic impacts
- Detailed examination of possible climate-change forces that could exacerbate the problems

ATMOSPHERIC RIVERS BRING WIND, RAIN, AND WAVES

EXTREME STORM SCENARIO: AR^{k}Storm

The **AR^{k}Storm** scenario hypothesizes severe storms that entrain huge amounts of moisture from the tropical Pacific and dump it on California over a several week period with firehose-like ferocity. The nontechnical term "Pineapple Express" is used to describe these storms.

Atmospheric rivers are embedded within much broader atmospheric storms referred to technically as "extratropical cyclones" (ECs). ECs are the winter-time analogue to hurricanes, but have much different structure. Also, they gain their energy largely from the pole-to-equator temperature contrast, unlike hurricanes, which draw their energy from ocean surface heat content. ARs are the business end of ECs because where the AR hits the mountains it can create extreme precipitation, flooding and high winds. In terms of impacts, an AR is to the broader EC it is embedded within, as the hurricane eyewall is to the broader hurricane of which it is a part. The importance and structure of ARs has become recognized recently through new satellite data and field experiments.

Because there is no suitable scale for atmospheric rivers, the storm scenario is named "**AR^{k}Storm**" to represent an atmospheric river (AR) with a value of 1,000 on a scale of atmospheric rivers to be determined by atmospheric scientists. The scenario storm then will be an "AR 1,000," and other U.S. West Coast storms will be scaled in comparison.

FLOODHAZARDS
Produced by an AR^{k}Storm Scenario

Flooding will be a major contributor to infrastructure damage, loss of use, and economic cost in the **AR^{k}Storm** scenario. A flood hazards team are working with FEMA and the State of California to determine the resultant flooding from an **AR^{k}Storm** Scenario for northern and southern California.

Based on the size and duration of this storm scenario, the **AR^{k}Storm** flood modeling team is working to provide:

- The geographic extent of areas vulnerable to flooding under the **AR^{k}Storm** meteorological model
- An **AR^{k}Storm** flood inundation map for the purpose of emergency response exercise
- A public workshop where localized flood management of the **AR^{k}Storm** can be addressed

This will provides a challenging emergency response scenario for the planning and preparedness community.

Geological evidence suggests that floods even greater than that of 1861–62 have occurred throughout California. Experts in paleoflood science will document geomorphic, biotic, and other information to reconstruct the occurrence and periodicity of these great floods.

LANDSLIDES
Relating Storm Size to Landslide Potential

Landslide scientists are creating new models to estimate the impact of landslides from the **AR^{k}Storm**, creating a new statewide landslide susceptibility map and using it to estimate future damages.

Scientists will acquire, digitize, and quantify maps and aerial photographs of landslides from past storms to estimate landslide potential. They will create a database of stratigraphy, soils, and slope for southern California and portions of northern California that can be used to determine landslide and debris flow susceptibility associated with storms like the scenario storm.

This will build on estimates of susceptibility to earthquake-triggered landslides prepared for the ShakeOut, with additional maps and analysis of debris-flow susceptibility and maps showing areas likely to be inundated by flooding and debris flows.

COASTAL HAZARDS
Assessing Coastal Vulnerability

A coastal inundation model completed in 2009 will translate the meteorological output data (wind, pressure, and so forth) into secondary hazards like coastal erosion and inundation.

The effort will lead to real-time understanding and prediction of coastal flooding, inundation, erosion, wave heights, current strength, and cliff failure on the entire Southern California coast.

The output of the model will be used:

- In the **AR^{k}Storm** scenario to determine plausible consequences of the hypothetical storm
- Beyond southern California and incorporate real-time data inputs for use in a real-time warning system to be used by emergency managers, lifeline continuity operators, and resource managers

Physical Damages

Once primary and secondary hazards are defined, a team of engineers will estimate the storms' impact in terms of the following:

- Physical damage
- Repair costs
- Restoration time for buildings, dams, levees, harbors, bridges, roads, water supply systems, and electric power.

To accomplish this, the **AR^{k}Storm** project will identify and solicit the participation of researchers, government employees, and other engineering professionals involved in the design, construction, operation, maintenance, or risk assessment of these systems.

Environmental and Health Impacts

The rainfall, flooding, winds, and physical damage to infrastructure from an extreme storm would likely also result in adverse physical, chemical, and ecological impacts on the environment in northern and southern California, including the possible extirpation of species.

The storm scenario will also allow recovery managers to better understand the types and nature of materials that would be in need of cleanup and disposal

In addition to the acute physical threats to safety posed by the storm, the possibility also exists for adverse health effects on humans and ecosystems.

Emergency Response

Like the ShakeOut Earthquake Scenario, the **AR^{k}Storm** scenario is scheduled to serve as the basis for the State of California's annual emergency response drill called Golden Guardian, possibly in 2012.

Forecast

Although uncertainty is an element of every forecast, key aspects of a winter storm of this magnitude can be predicted with varying accuracy and would give the public and emergency management community some time to prepare. The **AR^{k}Storm** scenario would provide a useful mechanism to exercise and test the use of forecasts in emergency management decisionmaking and will provide feedback to the atmospheric research and forecast community on what information requirements are not currently being met.

Policy

The Policy Section of **AR^{k}Storm** will focus on developing Winter Storm Scenario-based Policy Connections which include all four disaster management functions: preparedness, response, recovery, and mitigation. Special attention will be given to benefits from FEMA's new program which emphasizes lifecycle flood risk reduction through strategic mapping, assessment, and planning.

Economics

The **ShakeOut** Earthquake Scenario exposed the vulnerabilities associated with a large-scale regional disaster on theeconomy of southern California and the United States. Likewise, the **AR^{k}Storm** scenario economics team have developed a model of the California economy to examine the economic costs from damages and outages associated with the **AR^{k}Storm** scenario.

The Multi-Hazards Demonstration Project (MHDP)

The USGS Multi-Hazards Demonstration Project (MHDP) is working with partners to integrate earth science in urban areas with economic analysis and emergency response to increase community resiliency to natural disasters. A principle activity is the development of disaster scenarios to integrate science information into products usable by decision makers.

The first product from MHDP was the **ShakeOut** earthquake scenario of 2008 which assessed potential impacts from a large earthquake and associated damages on the southern San Andreas Fault. **ARkStorm** takes a similar approach in proposing and assessing a large winter storm scenario.

Public Hazard Awareness Campaign

Students from the Art Center College of Design in Pasadena, California, are working with the Multi-Hazards Demonstration Project to brand and develop a media campaign to raise awareness of natural hazards in general, with specific emphasis on the **AR^{k}Storm** scenario. The name **AR^{k}Storm** [Atmospheric River (AR) 1000 (k) = **AR^{k}Storm**] was partially derived from that effort.

AR^{k}Storm iPhone app

The app began at the Art center College of Design 2008. The students' task was to invent ways to turn disaster preparedness into a broad-based cultural value while also raising awareness and concern.

The AR^{k}Storm Team

Project Manager: Dale Alan Cox, USGS
Floods: Bill Croyle, DWR; Justin Ferris, USGS
Coastal: Patrick Barnard and Dan Hoover, USGS
Physical Damages: Keith Porter, Univ. of Colorado
Environmental: Geoff Plumlee and Charles Alpers, USGS
Landslides: Chris Wills, CA Geological Survey; Jon Stock USGS
Atmospherics: Marty Ralph and Mimi Hughes, NOAA/ESRL/PSD; Mike Dettinger, USGS Scripps
Visualization and support: Sue Perry, USGS; James Done, NCAR
Chief Scientist: Lucile Jones, USGS
Emergency Response: Mitch Miller, CalEMA
Economics: Anne Wein, USGS; Adam Rose, USC
Policy: KenTopping, CalPoly

More Information: website: http://urbanearth.usgs.gov, email: dacox@usgs.gov